Basewide Energy Systems Plan for Army Material and Mechanic Research Center

Volume I
Executive Summary
Final Report

Prepared for:

U.S. Army Corps of Engineers

Norfolk District

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August 1988

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BASEWIDE ENERGY SYSTEMS PLAN

FOR

ARMY MATERIAL AND MECHANIC RESEARCH CENTER

WATERTOWN, MASSACHUSETTS

ADDRESSING INCREMENTS A, B, C, E, F AND G

VOLUME I

EXECUTIVE SUMMARY

FINAL REPORT

PREPARED FOR:

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ARMY CONTRACT NO. DACA65-80-C-0015
JRB CONTRACT NO. 2-815-04-198

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AUGUST 1983

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PROGRAM WORK AT AMMRC

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PROGRAM WORK AT AMMRC (Continued)

*Additions and Updates, August, 1983

EXECUTIVE SUMMARY

This report presents the results of Increments A, B, and G, and the findings of Increments C, D, E, and F of the Basewide Energy Systems Plan for the Army Material and Mechanic Research Center (AMMRC), Watertown, Massachusetts, prepared by JRB Associates (JRB) under Contract No. DACA65-80-C-0015. The report includes the analysis of the energy use patterns at the base and the identification and evaluation of energy conservation opportunities. The obtained results indicate that AMMRC energy use can potentially be reduced 42 percent by FY 1985, compared to the FY 1975 energy use baseline.

The report is organized into three volumes: Volume I - Executive Summary, Volume II - Main Report, Facility Engineer Conservation Measures and Central Plant Report, and Volume III - Appendices and ECIP projects. The Main Report is divided into three sub-volumes. The first sub-volume contains four sections:

- Section 1. Describes the AMMRC facility and discusses the scope of the energy conservation study.
- Section 2. Provides a complete picture of energy use at AMMRC for FY 1977, a fuel use profile for the past three years and a discussion of future energy needs.
- Section 3. Contains JRB's analyses of the AMMRC energy supply and distribution systems.
- Section 4. Contains the results of JRB's analyses of potential energy conservation projects, and discusses the methods employed to determine project costs and energy savings.

Supporting information is provided in a series of appendices.

Information for this study was obtained through a series of site visits in which historical data were collected and detailed field surveys were

conducted for each building. A summary of the major AMMRC buildings is shown in Table 1, and their energy use is profiled in Figures 1 and 2. The summary of energy use of the past six years in Table 2 indicates that total energy use at AMMRC has declined since FY 1977 approximately 20 percent when comparing FY 1982 use. The baseline year for energy use measurements is FY 1975.

Figure 3 illustrates the total energy use in buildings at AMMRC by fuel type. Fuel oil accounts for over 57 percent of the total, while electricity accounts for over 41 percent. Natural gas accounts for about 1 percent of the total energy use. Peak fuel oil use occurs during the winter months as a result of the demand for building heat. The demand for electricity peaks during the summer, reflecting the extensive use of electrically-driven air conditioning equipment.

The central heating system was examined in detail. The central plant at AMMRC provides steam to the individual buildings through underground steam lines, many of which were found to be in poor condition. System losses due to various inefficiencies and leaks, together with boiler house energy use, accounted for 32 percent of the total fuel oil used at AMMRC. Improved insulation in the steam distribution system was recently installed, and will reduce some of the losses. A breakdown of the AMMRC fuel oil energy use for FY 1977 is shown in Figure 4.

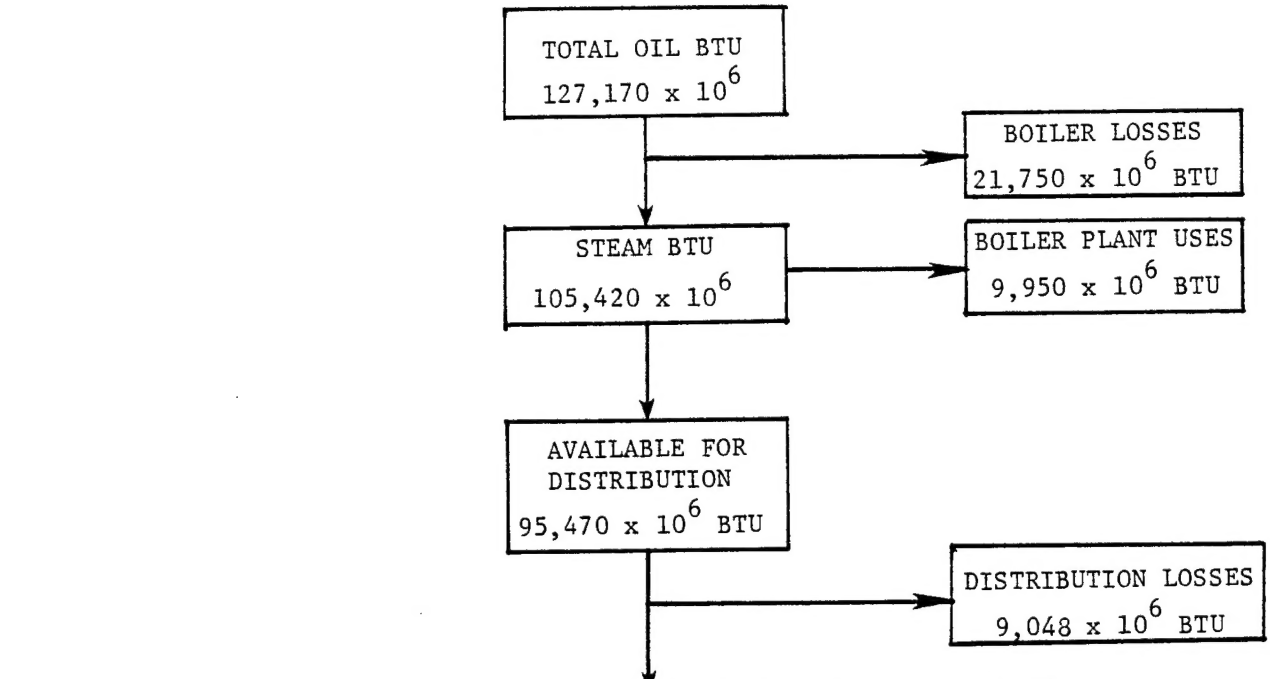
A similar analysis was performed for the electrical system. The highest electrical energy use is for lighting, amounting to over 40 percent of the total. Air conditioning, together with the operation of circulating fans and pumps, accounts for about 36 percent of base electrical energy use. Losses in the electrical distribution system are small, primarily resulting from the small physical size of the facility. The electrical energy use profile at AMMRC for FY 1977 is shown in Figure 5.

AMMRC has a very active energy conservation and management program, and submitted Energy Conservation Investment Program (ECIP) Projects include the installation of an Energy Management and Control System, thermal modifications to several buildings, and the insulation, repair and upgrading of the steam

TABLE 1. AMMRC WATERTOWN - BUILDING ENERGY USE AND INVENTORY SUMMARY

BUILDING CATEGORY	NUMBER OF BUILDINGS	TOTAL FLOOR AREA SQUARE FEET	TOTAL ENERGY USE IN FY 1979* Btu x 10^6
OFFICE	2	106,000	18,236.5
RESEARCH & DEV.	6	311,000	82,001.8
HOUSING	3	18,000	1,764.4
SHOPS	2	189,000	65,431.9
MISC.			1,700.0
TOTAL	13	624,000	169,134.6

* The total energy use excludes powerhouse energy use and other losses.



HEATING ENERGY USE	
BUILDING NO.	10^6 BTU
36	2,594
37	3,628
39	8,665
43	1,745
97	1,304
111	962
117/118	276
131	1,251
292	4,138
311	48,900
312	7,426
313	3,764
60	0
Other	1,700
TOTAL	86,353

DOMESTIC HOT WATER ENERGY USE	
BUILDING NO.	10^6 BTU
131	23.3
39	35.9
36	3.4
312	6.4
TOTAL	69.0

FIGURE 1. SUPPLY, DISTRIBUTION, AND END-USE OF FUEL OIL, FY 1977

TOTAL ELECTRICAL USE
$7,500 \times 10^3$ kWh

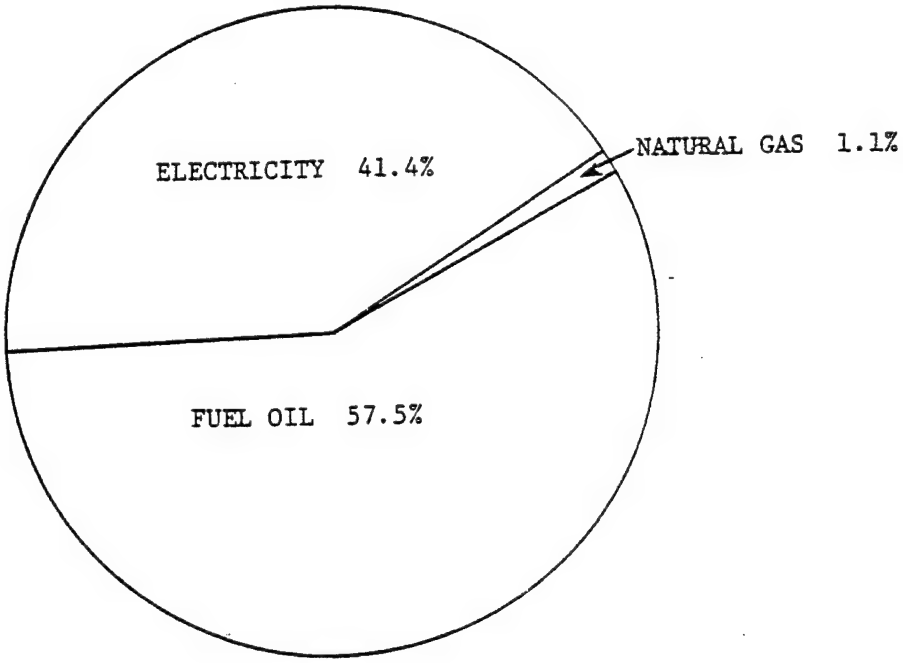
TRANSFORMER LOSSES (3%)
225×10^3 kWh

BUILDING NUMBER	DOMESTIC HOT WATER	COOLING (kWh/yr)	LIGHTING	FANS	PUMPS	PROCESS AND RESEARCH EQUIP.
36	0	8,800	200,000	164,160	6,840	100,000
37	14,943	15,425	243,000	39,000	0	93,000
39	0	466,500	551,000	294,000	0	223,000
43	0	0	104,000	10,104	22,896	118,000
97	0	20,299	105,000	30,456	18,544	33,000
111	4,629	0	5,338	500	500	10,246
117/118	26,956	0	4,106	0	0	24,945
131	0	45,546	495,000	25,775	56,225	136,000
292	0	483,000	242,000	185,350	151,650	117,000
311	6,241	135,976	263,000	42,104	22,896	258,000
312	1,875	93,806	362,000	224,845	31,155	148,000
313	7,706	64,898	460,000	36,380	8,385	211,000
TOTAL	62,350	1,334,250	3,034,444	1,052,674	319,091	1,472,191

FIGURE 2. ELECTRICAL ENERGY USE, FY 1977

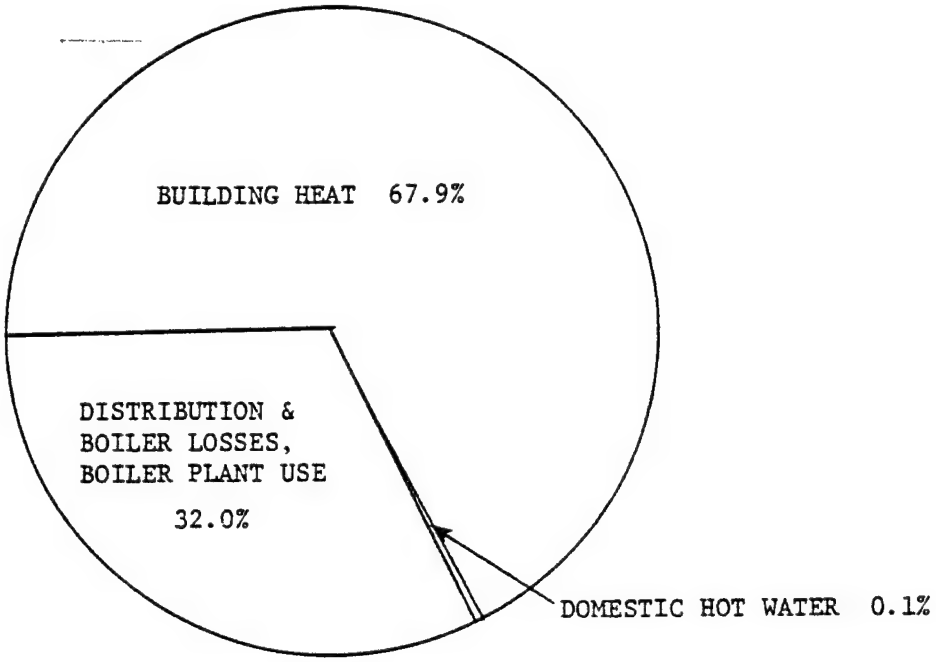
TABLE 2. ENERGY USE AT ARRADCOM-DENVER FY 1977 - FY 1982

FUEL TYPE	FY 1977 $_9$ Btu x 10^9	FY 1978 $_9$ Btu x 10^9	FY 1979 $_9$ Btu x 10^9	FY 1980 $_9$ Btu x 10^9	FY 1981 $_9$ Btu x 10^9	FY 1982 $_9$ Btu x 10^9
ELECTRICITY	87.00	87.95	85.31	80.690	80.098	79.447
NATURAL GAS	.033	.02	.02	1.331	1.604	1.520
FUEL OIL	127.17	134.23	120.77	93.095	103.120	91.412
TOTAL*	214.2	222.2	206.1	175.116	184.822	172.379



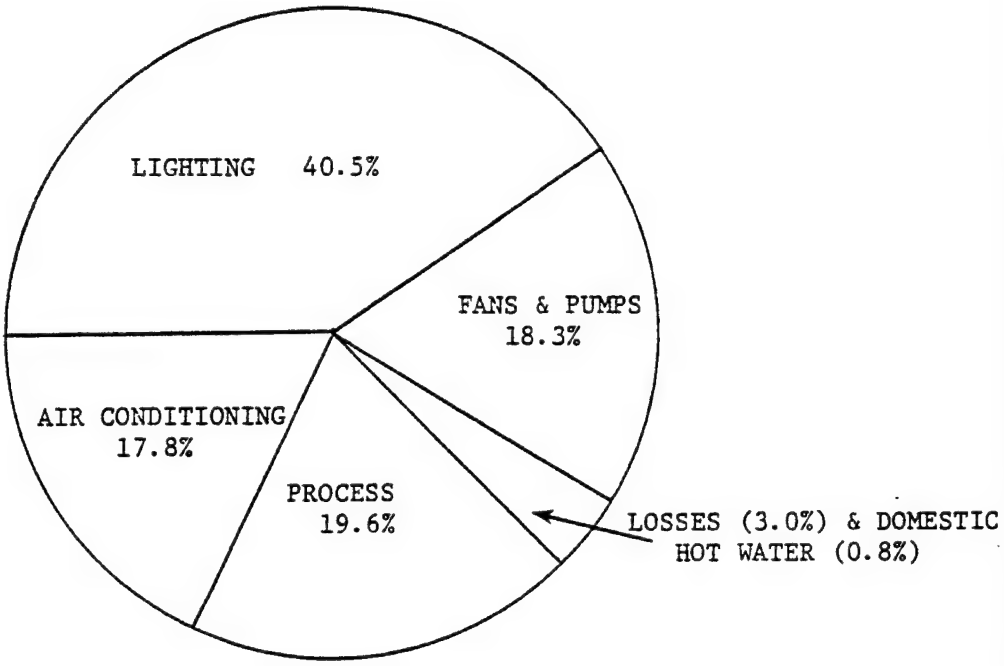
TOTAL ENERGY USE:- 206.1 x 10^9 Btu per Year

FIGURE 3. TOTAL ENERGY USE IN BUILDINGS BY FUEL TYPE, AMMRC, FY 1979



TOTAL HEATING FUEL EQUIVALENT: 127.17×10^9 Btu per year

FIGURE 4. END USE OF HEATING FUEL AT AMMRC, FY 1977



TOTAL ON-SITE ELECTRICITY USE: - 7,500 x 10^3 kWh per Year

FIGURE 5. ELECTRICAL ENERGY USE PROFILE AT AMMRC, FY 1977

distribution system. Additional energy conservation opportunities were developed by JRB, and were carefully analyzed for their engineering and economic feasibility. Table 3 shows a list of the projects considered and their status. The ECIP projects recommended are shown in Table 4, and the Increment G projects are shown in Table 5. The results of the ECIP analyses are presented in the Volume IIa-1, Subsection 4.4, report, and the Increment G analyses in Subsection 4.6. JRB also identified various operation and maintenance procedures and projects that could potentially reduce AMMRC's fixed facilities energy use by 2 to 4 percent.

The final results clearly indicate the potential for saving almost 40 percent in total energy use at the base by FY 1985, compared to the FY 1979 energy use baseline, through the implementation of all programmed and indentified energy conservation opportunities. Thus, the goals established in the Army Facilities Energy Plan should be exceeded by a comfortable margin. The magnitude of these potential savings is illustrated in Figure 6, which should be compared to Figure 1 to appreciate the fuel oil and electricity savings that can be made.

The work involved in Increments C and D is addressed in Volume IIa-2, and includes the analysis of solar, alternative, total and selective energy systems. The total and selective energy systems are essentially congeneration equipment sized to meet all or part of AMMRC's energy requirements.

The use of solar energy for heating and cooling offers the highest potential, followed by geothermal and photovoltaic energy sources. The long range (FY 2000) goal includes substituting alternative energy sources for 20 percent of the energy supplied by petroleum fuels, an amount equivalent to approximately 25 billion Btu per year. None of the solar energy systems had a positive life cycle cost, but two had a payback period less than 15 years and several had a payback period of 15 to 20 years. Those projects are:

- Solar heating of domestic water
- Solar heating of buildings
- Solar heating of oil tanks
- Geothermal energy.

TABLE 3. POTENTIAL ENERGY CONSERVATION OPPORTUNITIES

OPTION DESCRIPTION	E/C	B/C	ENERGY SAVINGS MBtu/Yr	CWE ($)	ANNUAL SAVINGS ($)	PAYBACK (YRS)	STATUS
CENTRAL HEATING/COOLING PLANTS							
Refuse Burning	2.85	0.2	4,469		41,000		NO
Boiler Economizer	2.45	0.33	1,537	627,892	13,150	47.8	NO
Boiler Water Treatment							N/A
Variable Speed Chiller Motor							N/A
Return Condensate							N/A
Insulate Pipes							PROG.
EMCS							PROG.
Automatic Condenser Cleaning							N/A
Reset Chilled Water							N/A
Chiller Economizer							N/A
Boiler Plant Modification	36.3	7.74	2,053	57,000	18,944	3.0	ECIP
Oxygen Compensation for Boiler Controls	6.4	0.31	512.2	19,535	(1,561)	(51.0)	NO
BUILDING SHELL							
Replace Windows	5.37	1.33	6.77	1,256	71.0	17.7	NO
Storm Windows							N/A
Wall Insulation (Interior)	5.1	1.3	28.4	5,534	295	18.7	NO
Roof Insulation	22.2	5.2	215.6	9,716	2,162	4.5	INCR. G
Reduce Solar Heat Gain							N/A
Vestibules	0.61	0.14	2.95	4,837	30	160.5	NO
Reduce Door Size (Garage)	37.4	8.63	96.18	280,000	25,339	2.9	ECIP
Loading Dock Strip Doors	30.61	2.88	57.62	1,882	549	3.42	O&M
Wall Insulation (Exterior)	2.7	.7	285.0	104,676	2,953	35.4	NO
Eliminate Unnecessary Roof Vents							N/A
LIGHTING							
Task Lighting							N/A
Use Higher Efficient Ballasts	8.08	0.88	0.6	74	5	15.03	NO
Reduce Height of Luminaires							N/A
Add Switching							N/A
Use Automatic Dimming Controls							N/A
Use Higher Efficient Lamps							N/A
Auto Shutoff Controls							N/A

TABLE 3. POTENTIAL ENERGY CONSERVATION OPPORTUNITIES (CONTINUED)

OPTION DESCRIPTION	E/C	B/C	ENERGY SAVINGS MBtu/Yr	CWE ($)	ANNUAL SAVINGS ($)	PAYBACK (YRS)	STATUS
BUILDING HEATING AND COOLING							
Ground Source Heat Pump Chiller	17.56	3.45	4,949	281,797	39,835	7.07	ECIP
Reduce Air Flow Rates							N/A
Shut Down Ventilation Systems							PROG.
Eliminate Unnecessary Roof Seals							N/A
Replace Gas Pilots with Electric Ignitors							N/A
Heat Wheels for Recovery							N/A
Temperature Setback							PROG*
Warm Up Cycle Controls							PROG*
Rezone Heating System							N/A
Economizer Controls							N/A
VAV Systems							N/A
Shut Down Air Conditioning Systems							PROG*
Spot Cooling							N/A
Dead-band Thermostats							N/A
Air Stratification							N/A
*EMCS							
Chiller Waste Heat Recovery for Supporting Reheat Energy	2.1	1.2	2,200	1,040,000	47,115	22.1	NO
DOMESTIC HOT WATER							
Hot Water Recirculating Shutdown							N/A
Use Local Hot Water Heaters							N/A
Use Solar Heating 3 Panel	3.96	0.50	28.48	7,200	177	40.7	NO
120 Panel	5.63	0.72	1,080.2	191,718	6,712	28.57	NO

*On EMCS design currently in progress

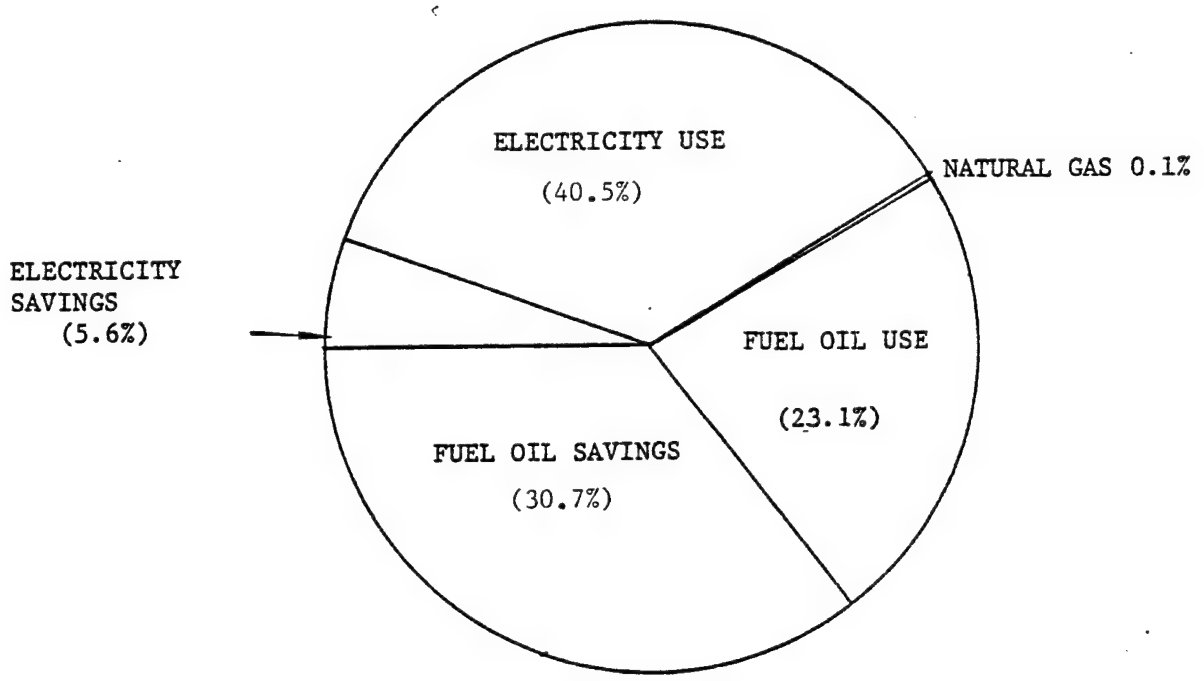
TABLE 4. PRIORITIZATION LIST OF ENERGY CONSERVATION PROJECTS

Project Number	Project Title	Energy-to-Cost Ratio	Energy Savings 10^6 Btu/yr.	CWE
4.4.1	Reduce Garage Door Openings and Add Ceiling Insulation	37.4	9,618	280,000
4.4.2	Boiler Plant Modification *	36.5	2,053	57,000
4.4.3	Ground Source Heat Pump Chiller	17.1	4,949	289.000
TOTAL			16,620	

TABLE 5. SUMMARY OF INCREMENT G PROJECTS

PROJECT	$\frac{E}{C}$	$\frac{B}{C}$	$\frac{EC}{CC}$	PAYBACK (YRS)	FUEL ENERGY SAVINGS (10^6 Btu)	(10^6 Btu)	ELECT. (10^6 Btu)	ANNUAL ENERGY SAVINGS (10^6 Btu)	ANNUAL COST SAVINGS ($)	CWE ($)
Roof Insulation	22.2	5.2	7.6	4.5	163.5	-	52.1	215.6	$2,162	$9,716

*Project CWE less than $100,000, therefore not an ECIP project but qualified as an Increment G project.



TOTAL PROJECTED ENERGY USE FY 1985: 121.3×10^9 Btu

TOTAL PROJECTED SAVINGS OVER FY 1975 BASELINE: 71.8×10^9 Btu

NOTE: Percentages in this Figure are directly comparable to those given in Figure 3.

FIGURE 6. TOTAL PROJECTED ENERGY USE AND SAVINGS AT AMMRC, FY 1985 (Based upon FY 1975 Energy Use)

The potential for use of total and selective energy systems is also assessed. The long range (FY 2000) goal for these sources is to reduce the consumption of petroleum fuels by 35 percent, equivalent to approximately 44 billion Btu per year. At this time, none of the currently available total or selective energy systems had a positive life cycle cost.

The primary purpose of Increment E (Volume IIc) of the Basewide Energy Systems Plan for AMMRC was to evaluate the conversion of the existing oil-fired central heating plant to a coal-fired facility. Analysis has shown such a conversion to be impractical at this time due to economic reasons.

The configuration and basic operation of the existing system was obtained from work done under previous increments. The load profile used in this analysis is the initial profile established in Increment A modified by energy conservation options recommended in all other increments. Options initiated by the base over and above those recommended under other increments are also considered.

The proposed conversion to coal was investigated as an immediate conversion by replacing oil-fired boilers with coal-fired boilers. Neither coal supply nor required air pollution controls were technical obstacles to coal conversion. Adequate amounts of coal are available from Pennsylvania. Although AMMRC is located in a critical area with respect to air pollution, the characteristics of Pennsylvania coal and the availability of pollution control equipment combine to provide compliance to emission limits.

Table 6 summarizes the economic analysis for immediate conversion to coal. The initial comparison (options 1 and 2) shows conversion can not be justified at this time. The coal system would have to be 30 percent less than estimated to change this conclusion. Options 3 through 6 show the sensitivity of the analyses to existing system life and to maintenance costs. If the existing system must be replaced immediately, a coal replacement (option 2) is more economical than an oil replacement (option 3). If the oil system can last until 1989, then replacement with oil systems (option 4) is more economical than coal. Since the existing system is expected to last another

LCC Period	No.	Option Description	1983 Present Worth Values ($1000)					
			Initial Plant Cost	Total of Annual Maintenance & Operation[1]	Nonannual Replacement	Fuel Oil	Coal	Total Life Cycle Cost (LCC)
25 Year Life Cycle Cost from 1988 to 2013	1	Existing System	0	1,400	0	5,255	0	6,655
	2	Replacement coal boilers, minor building modifications	4,500	1,935	0	0	1,555	7,990
	3	Existing system with 1987 replacement oil boilers	0	1,400	1,980	5,255	0	8,635
	4	Existing system with 1992 replacement oil boilers	0	1,400	1,230	5,255	0	7,885
	5	Existing system with 5% maintenance cost increase per year	0	2,280	0	5,255		7,535
	6	Reduced coal system maintenance	4,500	1,400	0	0	1,555	7,455

[1]Excluding fuels

TABLE 6. SUMMARY OF CENTRAL HEATING PLANT OPTIONS, AMMRC, WATERTOWN, MA

25 years (until the year 2013) but need only last another 6 years (1989) for oil to be more cost effective than coal systems, the LCC is not sensitive to the existing system life. The maintenance costs of the existing system would have to increase over 5 percent per year for oil systems to be more costly than coal systems (see option 5). Coal system maintenance costs would have to be much less than oil system maintenance for coal to be more economical than oil (see option 6).

Based on the analyses done, it is recommended than the oil-fired plant be used until the end of its useful life. At that time a new coal-fired system should be considered.

Increment F, the Facility Engineer Conservation measures (Volume II b), of the Basewide Energy Systems Plan for AMMRC, evaluated energy conservation projects that can be done under Facility Engineering programs and presents a summary of projects implemented and planned.

Four Facility Engineering energy conservation projects were evalauted and are summarized in Table 7. The first project and select parts of projects 2 and 3 are recommended for implementation and can save 7.7 billion Btu per year, or 4 percent of the 1975 baseline energy use. Those parts of the second and third projects are not recommended due to poor economics. An evaluation of the HVAC controls (project 4) indicated satisfactory operation and maintenance and the option is not recommended.

TABLE 7. SUMMARY OF INCREMENT F PROJECTS

PROJECT		IMPLEMENTATION		SAVINGS		
No.	Name	Cost**	Manhours	MBTU/Year	$/Year	SIR
1.	Storm Windows & Doors - Building 111	$ 1,400	16	78	400	4.6
3.	Window Improvements - Building 311					
	Reduce Window Area	$183,900	12,850	7,614	40,500	3.4
	Replace Windows	$720 Window	3/window*	5/window*	27/window*	0.6
2.	Replacement of Family Housing Unit Heater Systems (Bldgs 111,117,118)					
	Night Setback	$ 1,575	8	17	130	1.1
	Burner Replacement	$ 22,900*	160*	25*	200*	0.1
4	Evaluation of HVAC Control Performance		N/A - SEE TEXT			
TOTALS		$186,875	12,874	7,709	41,030	

**Includes design and SIOH fees.

*SIR less than 1.0, therefore not included in total.